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REVIEW DRAFT

SAFETY GUIDELINES FOR MAN-RATING ALTITUDE CHAMBERS

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SAFETY GUIDELINES FOR MAN-RATING
ALTITUDE CHAMBERS

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SECTION 1

SCOPE

1.1 PURPOSE

The purpose of this directive is to provide safety guidelines as candidate safety requirements in order to minimize risk from environment to personnel and equipment during the design, fabrication, testing, and operation of altitude chamber test complexes.

1.2 APPLICATION

Center Program Offices will select from these guidelines pertinent requirements and apply them as necessary. The Center Program Offices should compare the benefits to be derived with the problems of implementation and coordinate any major deviations with the appropriate Safety Director, Headquarters Program Office. The following types of chambers are covered by these guidelines:

a. Altitude Chamber (Physiological checkout for pilots and physiological training of test team members.)

b. Vacuum Chambers

c. High Oxygen Partial Pressure Chambers

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SECTION 2

DOCUMENTS

The following documents are pertinent to this issuance:

NPD 1701.1	Basic Policy on Safety
NMI 1138.12	Functions and Authority-Director Manned Space Flight Safety Office
NMI 1130.10	Role and Authority-NASA Director of Safety
NHB 1700.1	NASA Safety Manual
NMI 1700.2	Manned Space Flight Safety Program
CFR Title 10, Part 20	Standards for Protection Against Radiation
NMI 8900.1	Medical Responsibilities and Relationships in the Manned Space Flight Organization
SPD-1	System Safety Requirements for Manned Space Flight

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SECTION 3

DISCUSSION

3.1 MAN-RATING

Man-rating can be defined as the method which assures that manned systems have met the requirements established for safety and man-machine relationships so that the system/hardware can be officially certified as suitable for man's use.

Implementation of man-rating is accomplished by applying a combined process of specifically identified engineering techniques and close management control throughout the life-cycle of a program. The safety aspect of this process consists of the following major elements:

a. Establishment of safety requirements for each phase of development and operation.
b. Implementation of these safety requirements into design, reliability, quality control, test, manufacturing, operation, and maintenance.
c. Evaluation of the man-rating process at all key management checkpoints.
d. Identification of a man-rating authority to make trade-off, scheduling, and cost decisions.
e. Application of a Personnel Program which (1) assures timely availability of qualified and certified personnel, (2) creates and maintains an awareness of the importance of safety, and (3) establishes criteria for time on job to avoid operator fatigue.

3.2 BASELINE

The candidate safety requirements presented in this directive represent the first step in the man-rating process (a. above). They provide the man-rating baseline by which safety may be implemented during the remainder of the process.

Many of the safety requirements contained herein are inherent responsibilities of other technical disciplines. However, the safety impact necessitates their collateral delineation as safety requirements. Their satisfaction should continue to be accomplished by the cognizant discipline. The safety activity will monitor this accomplishment to assure that the overall interests of safety are satisfied.

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SECTION 4

REQUIREMENTS

4.1 FACILITIES

Facility guidelines for altitude chambers are described as follows.

a. An alternate access route to and from the chamber should be available in the event that the primary access route is blocked.

b. Medical assistance will be immediately available for the purpose of providing prompt attention to seriously injured personnel. Ambulance service should be on a standby alert basis.

c. A clean or appropriate contamination controlled room is required for suiting and checkout as well as preparing and maintaining all materials and equipment for use in an oxygen-rich environment in an oxygen-compatible condition.

d. A redundant and independent power supply should be provided to insure the capability of operating all critical and emergency functions if a primary power loss occurs.

e. An "open-line" vent capability should provide "fail-safe" venting for all cryogenics and unwanted gases. Traps, flapper valves and low spots tend to collect moisture and can freeze closed during cryo-venting and certain weather conditions.

f. Where feasible, chambers should be provided with manual actuation of controls for all critical systems so that they will never be inoperable.

g. At least one air lock attached or integral to the chamber to allow ingress and egress without creating a change in the pressure environment should be provided.

It will also provide the capability to readjust environmental pressures without discomfort or injury to test personnel. The air lock should meet the following criteria:

(1) Large enough for at least three men.

(2) Doors shall allow rapid ingress and egress.

(3) Air lock cycle time shall be minimal for the activity involved.

(4) Provide read-out information for critical systems conditions inside the air lock.

(5) Provide windows and lights to allow complete observer coverage of air lock condition.

(6) Provide a redundant system for supplying breathing air or breathing oxygen.

(7) Provide for emergency repressurization.

(8) Pressure relief valves or other safeguards should be provided in the event of overpressurization.

h. Observation windows in chamber walls or closed circuit TV to allow complete visual coverage of the chamber activity should be provided.

i. Interior lighting for the chamber should include a separate emergency backup system.

j. Redundant communications systems between control console, inside chamber, test article, and air lock should be installed when feasible.

k. All systems will be designed fail-safe, if possible, and the interruption of gas flow, fluid or electrical current should not, by itself, cause a critical condition.

l. All critical service lines shall be routed and protected to preclude damage from any cause other than a catastrophic occurrence. Redundant systems shall be adequately separated from each other.

m. Lines providing non-compatible materials or services shall be run in separate protective shields.

n. Where feasible, sharp corners and other protrusions should be eliminated which might cause damage to personnel, suits or equipment.

o. All primary controls should be located outside of chamber and air lock. In cases where inside controls are used for these functions, external override should be provided. Control of the ground testing activity must be the responsibility of the test conductor, who is not normally exposed to abnormal environments.

p. A hyperbaric chamber qualified for oxygen enrichment and containing appropriate certified medications and oxygen breathing apparatus will be supplied suitably near the altitude chamber. The hyperbaric facility should be capable of operating on self-contained resources for a period of up to eight hours. The hyperbaric chamber is required to perform any emergency recompression or decompression functions required in medical treatment and should be adequate in size to handle the maximum number of men that might require its use.

q. Emergency repressurization capability will be required for the air locks and altitude chambers. A redundant means of performing this function should also be provided.

r. Repressurization shall be accomplished without contamination of the chamber or its contents except for emergencies repressurization.

s. All cryogenic systems will be provided with relief valves and burst disks which vent to the outside of the chamber. Vents must be sized to handle maximum flow.

t. Protective rails shall be provided between test personnel and cold walls or heaters.

u. The pumping system shall be capable of handling any outgassing emanating from the test specimen.

v. Special attention will be given to all elements of chamber and test setup, to assure compliance with the requirements for compatibility in an oxygen-rich environment.

w. Inside the chamber, equipment shall be anchored and occupants protected against high velocity air movements created by explosive or rapid change in pressure. Safety gratings and baffles over ports shall be provided.

x. In cases where the presence of toxic or explosive gases may be expected, an appropriate purge system shall be provided.

y. To prevent oxygen enrichment of chambers or air lock atmospheres, an appropriate purge system capable of supplying a sufficient amount of normal air shall be provided.

z. All electrical equipment, including lamps, shall be compatible with the low pressures expected during altitude exposure. Emergency power shall be available to operate the prime controlling valves and monitoring system.

4.2 LIFE SUPPORT SYSTEMS

a. Breathing air or breathing oxygen shall be furnished to manned areas at all times during a manned function. The breathing supply should be redundant during altitude chamber operations since many single point failures could render one system inoperative.

b. Continuous monitoring, to keep all key test personnel informed of test area conditions, should be performed so that they will be capable of providing quick and coordinated response, if an anomaly occurs. The monitor readouts will be displayed on the master control console and in all other closed areas occupied by personnel. An alarm will also be provided to warn of any out-of-tolerance conditions.

c. A redundant communications system will be available to all key members of the test team regardless of location.

d. Adequate environmental control will be provided in all closed areas in order to maintain personnel in an alert and responsive posture during the test cycle.

e. Any oxygen system having the main supply of oxygen located externally to the chamber, shall have a check valve to prevent outward oxygen flow from the internal chamber manifold in the event that damage to external plumbing occurs.

f. Disconnects which are used to supply breathing air or breathing oxygen for men inside the chamber shall be designed to prevent failure due to leaking or blow off. The lines shall be secured to structure members wherever feasible.

4.3 TEST SUPPORT SYSTEMS

a. Instrumentation readouts, at the master console, are required for all critical functions. These readouts should be redundant.

b. Specially designed relief valves will be required in some tests to preclude over-pressurization of the test specimen. This pressurization differential may be either positive or negative.

c. A full complement of communications modes, including visual, audio and biomedical, is required when manned operations are being conducted.

d. Oxygen flow limiters and/or monitoring devices are required to insure against oxygen partial pressure increases.

4.4 MATERIALS EVALUATION

A rigid materials evaluation and control activity is required to assure the compatibility of the materials and commodities involved in the total test complex. This evaluation will identify all attendant hazardous characteristics including, but not limited to, toxicity, ignition temperature and explosive potential. This function is required to preclude any hazardous condition that might occur as a result of the combined effects of materials and environment.

4.5 ALTITUDE CHAMBER OPERATIONS

a. Detailed operating procedures are required for all activities performed in the altitude chamber complex including service and maintenance.

b. Procedure verification is required for all test and operating activities. This verification also requires actual unmanned pre-test runs.

c. All test complex elements should be subjected prior to a manned test or series of manned tests to at least 110% of the anticipated test load. The pre-test checkout should be performed at least once daily.

d. All items of hardware or test equipment which will be exposed to the altitude environment will be analyzed to assure that they are not adversely affected by the pressure differential.

e. Test observers are required in sufficient numbers to continually monitor the test activity for the occurrence of any undesired event.

f. All critical systems test values will be identified including the + or - tolerance and will be posted at strategic locations in the test complex.

g. Personnel will be protected from noise levels that may accrue from rapid repressurization.

h. Test and rescue training and certification including medical qualifications are required for all participating personnel.

i. Medical qualification requirements for test subjects and critical support personnel will be established.

j. An Altitude Chamber Operator Training and Certification Program is required to include instruction in physiological aspects of chamber operations.

k. All altitude chamber operations will consider the adequacy of work-rest cycles for all participants to minimize the reduction in personnel performance resulting from stress and fatigue.

4.6 EMERGENCY AND RESCUE

a. Detailed emergency, rescue and backout procedures will be developed. The procedures will provide the basis for determining the content of the rescue team and its required training.

b. Rescue teams shall be identified, trained and certified.

c. Rescue equipment will be provided and stored adjacent to the test area. This will include fire-resistant protective suits, breathing apparatus, fire fighting equipment and other items of protective gear as identified by the emergency procedures.

d. A fire sensing and alarm system will be provided in strategic locations throughout the test complex.

e. A deluge system shall be provided for fire protection. It shall be designed such that inadvertent activation is precluded and its use shall not cause generation or release of toxic gases. This system shall have automatic detection and manual activation capability when particular fire hazards so warrant.

f. The electrical system design shall be such that momentary power failure will not cause actuation of any chamber emergency system.

g. A medical doctor will be present at the biomedical console during all tests that require personnel in the altitude chamber.

h. Protective means will be provided to prevent freezing of fire fighting materials.

i. Standby crews qualified to operate hyperbaric chambers and treat casualties in the chamber will be available.

4.7 MAN-RATING REVIEW BOARD

At each facility having an altitude and/or hyperbaric chamber, a man-rating review board or Operational Readiness Inspection Committee shall be established. The board/committee will be responsible for ascertaining the adequacy of existing requirements and procedures for conducting operational tests of facilities and equipment involving man in a varying pressures, oxygen-rich or potentially oxygen-rich environment and recommending appropriate changes.

a. Membership

A chairman and an alternate board/committee chairman will be designated. In addition, the board/committee will consist of an executive secretary and not less than eight members. The board/committee will report to the Center Director or his designated representative. The membership of the board/committee will include a representative of the office supplying test crewmen and representatives from the following specific disciplines:

(1) Occupational and environmental medicine
(2) Safety
(3) Reliability and Quality Assurance
(4) Facility Engineering, Management, Test Engineering, and others as appropriate.

b. Functions

The functions of the board/committee will be to review the designated facility and/or equipment and assess the state of operational readiness in the following areas:

(1) Adequacy of design, reliability, and construction.
(2) Proper organization and staffing for operation.
(3) Definition of responsibility interfaces between all organizational elements involved in the operations.
(4) Proper level of training of operating personnel.
(5) Adequacy of pre-operational inspection and quality control, and shakedown testing.
(6) Plans and procedures for normal and emergency operation.
(7) Documentation.
(8) Available and adequacy of supporting emergency safety services and facilities (fire, medical, security, and safety).

(9) Procedure and documentation for configuration control of facility and test article.

(10) Compliance in all respects with the minimum guidelines specified herein.

(11) Any other factors having a direct or indirect bearing on safe operation of the facility or equipment.

(12) Adequacy of the inspection and quality assurance requirements associated with the design, modification, operation, and maintenance functions.

(13) Safety from human factors and industrial health standpoint.

(14) Performance of an adequate failure mode effect analysis.

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SECTION 5

MAN-RATING IMPLEMENTATION ASSURANCE

5.1 MARGIN OF SAFETY TESTING

Provisions must be made to assure that adequate validation tests are performed on critical devices or components to determine the degree of hazard or margin of safety in design. Induced failure tests should also be considered for demonstrating the failure mode of critical components. Conclusions derived from tests, and subsequent redesign and testing must be clearly and adequately substantiated by valid and specific test data.

5.2 SAFETY MONITORING

Observation of altitude chamber operations should be accomplished as necessary to ensure adherence to safety principles and compliance with safety requirements and checklists. Normally, the degree of monitoring necessary will vary depending upon such factors as the nature of the operation, the quality of technical data available, the personnel involved and the type of facilities available. Other factors may also be decisive and the degree of monitoring should be periodically evaluated as the state-of-art progresses.

5.3 REVIEW OF CHANGES

When changes are proposed for equipment design or procedures, the man-rating review board should review the proposed configuration to identify and resolve any potential hazards that may be introduced into the system.

5.4 POST-OPERATIONS EVALUATION

Safety personnel should participate in post-operations reviews and obtain a safety evaluation of areas in which anomalous conditions were revealed. This safety evaluation will provide guidance in planning future operations and establishing corrective action to reduce hazards. Areas for consideration include:

a. Safety adequacy of procedures and protective equipment.

b. Response of warning devices and effectiveness of emergency procedures and equipment.

c. Effects of unforeseen events.

d. Effects of human capabilities and constraints on personnel safety.

e. Provision for pertinent inputs to data file.

f. Assuring that applicable activities receive pertinent information for appropriate corrective action.

5.5 DOCUMENTATION REQUIREMENTS

5.5.1 COORDINATION AND APPROVAL

All requirements, planning and procedural documentation applicable to critical components must undergo an established coordination and approval process and be subject to a formal updating, revision and accounting system.

5.5.2 DESIGN AND CONFIGURATION CHANGES

Design and configuration changes should be incorporated into applicable test, maintenance, operation and facility documentation whenever such changes require modification to established operations and maintenance.

5.6 TRAINING AND CERTIFICATION

5.6.1 TRAINING PROGRAMS FOR TEST PERSONNEL

Test and operations organizations should normally be responsible for developing minimum training standards for conducting training programs for the purpose of qualification and certification of all operating and test crew personnel.

5.6.2 PERSONNEL SUBSYSTEMS

Personnel subsystems should be developed for all manned operations. These subsystems will establish the requirements for all positions, skills, operational and maintenance procedures, training and personnel certification. The personnel subsystems will apply to both test and operation functions. Appropriate documentation such as position guides, job procedures, training material and operation/maintenance manuals shall be selected and/or developed as part of the personnel subsystem.